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Burst Test of the Best Buy Warhead

by James M. Bender

ARL-TR-2560 August 2001

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5069

ARL-TR-2560 **August 2001**

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Abstract

The Best Buy program is a U.S. Navy development effort with the objective of gun launching a 5-in (127-mm) diameter, rocket-assisted, guided projectile to a range of 100 nautical miles (184 km) where the cargo will be dispensed over the target area. It is fired from the Mark 45 cannon or its improved variant. The cargo consists of 143 U.S. Army M-80 grenades. The intended target set is identical to that of the Army's M483 and M864 155-mm projectiles. The Best Buy projectile's mission is to replace the need for the U.S. Navy to emplace U.S. Marine towed artillery assets ashore in an amphibious assault. The minimum requirements for the Best Buy projectile are that it must be fired from 25 nautical miles (46 km) offshore to reach targets inland by an additional 25 nautical miles. In anticipation of future range requirements, the range requirement was extended to 63 nautical miles (116 km), and 100 nautical miles (240 km) is desired. This report covers Phase 1 of the warhead development program performed by the U.S. Army Research Laboratory (ARL) working in cooperation with the Naval Surface Warfare Center, Dahlgren Division (NSWC-DD) at Dahlgren, VA.

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1. Introduction

From 1990 to 1996, the U.S. Army Research Laboratory (ARL) investigated the use of polymer composite materials for increased capacity artillery projectile shells under the High Capacity Artillery Projectile (HICAP) program. HICAP is a concept 155-mm cannon-launched artillery projectile (Figure 1) that can carry twice the payload of the current cargo carrier, the M483, with an overall weight increase of only 17 lb (the M483 weighs 103 lb). The projectile is greater than twice the length of the M483 and consists of fore and aft subassemblies. These sections are assembled just prior to firing by means of a novel snap joint. It is stabilized by a set of six deployable fins and a slip obturator prevents in-bore rotation. HICAP's two warheads consist of a polymer composite material shell that carries a payload of grenades. The forward warhead dispenses the grenades by pressurizing and bursting the warhead and disseminating the grenades radially. The aft warhead dispenses grenades through the base by initiating an ejection charge at the front of the aft shell and pushing them through the base, shearing the connection. Directional strength is an advantage of composite materials, in addition to the significant weight savings. It is strong in longitudinal compression to resist launch forces, yet can be tailored to have the desired hoop strength, allowing the forward shell to burst at a design pressure of 2,500 psi (17.5 MPa). This technique was demonstrated under the program in 1996. The technology was transferred to the Best Buy program at NSWC-DD in 1998 under a Memorandum of Agreement (MOA).

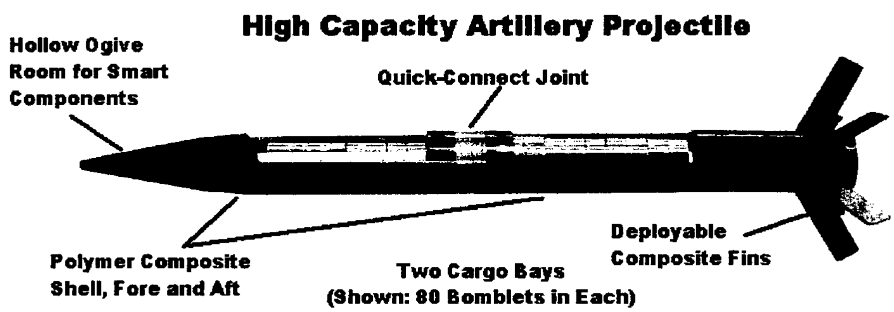


Figure 1. High capacity artillery projectile (HICAP).

The Best Buy projectile's diameter is 1 in smaller than HICAP and carries modified U.S. Army M-80 dual purpose improved conventional munition (DPICM) grenades. There are 13 layers of 11 grenades arranged, as shown in Figure 2. The interstitial spaces provide room for the burster charges, which are made of a slow burning propellant initiated by a proximity fuze. The gradual

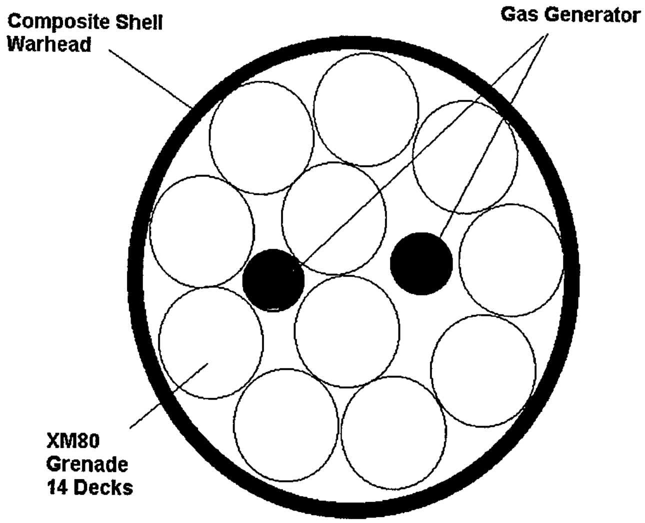


Figure 2. Grenade layout.

increase in pressure (rise time of 40–50 ms) evenly pressurizes the shell until it bursts, dispensing the grenades without damaging them. Bursting is designed to occur at 2,000 psi (13.8 MPa), when the projectile is approximately 3,300 ft (1,065 m) above target area. The grenades are designed to fragment when they strike the ground or fire a shaped charge penetrator jet upon impact with hard targets such as armored vehicles.

2. Methodology

Two pretests were performed to establish the optimal burst pressure and amount of propellant. Considering the cost of an actual polymer composite case, a steel case of equal strength was used. The first of these two tests dispensed 11 Lexan bars that ran the full length of the shell. These bars simulated the volume taken up by the grenades. This provides a close approximation to the void space that would be pressurized by the propellant to aid in verifying the charge mass. A smokeless black powder, Pyrodex, was utilized as the energetic material and was initiated remotely by det cord. The assembly was placed in a tent made of Kevlar blankets. The expected maximum grenade ejection velocity was between 100 and 200 ft/s (32 and 64 m/s). These blankets had been previously tested to resist penetration by a grenade traveling at up to 400 ft/s (130 m/s). The tent was constructed inside an armored containment vessel. The test setup is shown in Figure 3. A witness board can be seen in back of the tent with increasing diameter rings. These rings aid in measuring ejection velocity of the grenades by high-speed video with a capture rate of 1000 frames/s. The test shell was packed

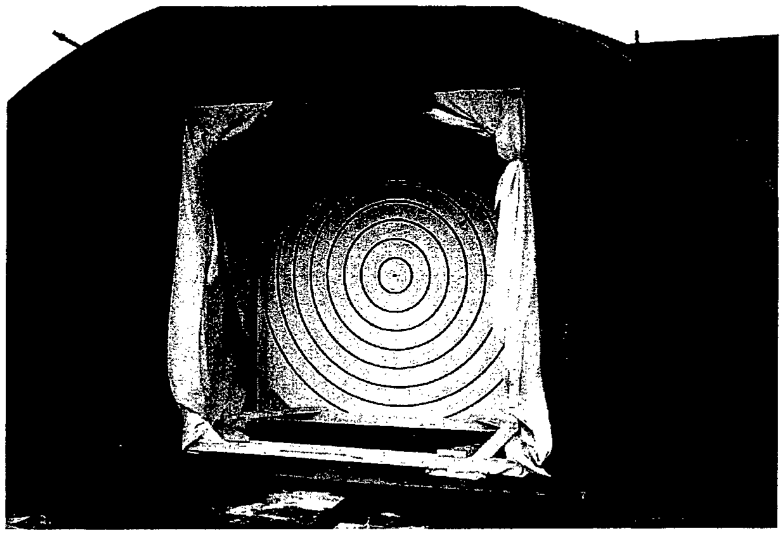


Figure 3. Kevlar tent inside containment vessel.

with the payload and charge (Figure 4) and then placed between two armor plates that are bolted together by steel rods (Figure 5). This prevents any grenade expulsion out of either end. In an actual Best Buy warhead, one end would connect to the ogive and the other to the spent rocket assist section.

Both of those assemblies have sufficient inertia to resist grenades from expelling axially. For this test, a single burster charge was used, as opposed to the two in the tactical configuration shown in Figure 2. The test warhead is then hoisted into place and centered axially in front of the witness board, as shown in Figure 6. The grenade velocity is measured by tracking the grenades' trajectory on the high-speed video. Those grenades that hit the steel support bars are not tracked. The burst pressure is measured by a transducer mounted in one of the plates over the cylinder. Two video views are recorded. The first is a view of the entire witness board and the other is a close-in view, capturing the first four rings. The digital video is processed into audio visual information files for viewing on a personal computer, where each frame can be examined to obtain accurate expulsion velocities.

The second test was performed similarly to the first, except that inert M80 grenades were used as the payload. Most of the test hardware was reusable. The test warhead is shown in Figure 7. The third test was conducted using a polymer composite shell nearly identical to the one that will be used on an actual projectile (Figure 8). A total of 143 inert M80 grenades were placed inside. It is fabricated using a Hercules IM7/8551 fiber-resin system. It is 0.080 in (2 mm) thick and is able to withstand 150,000 lb (68 kN) of axial force—more than is applied by a 20-lb ogive during a 7,000-g launch. Figure 8 shows the composite shell with grenades loaded.

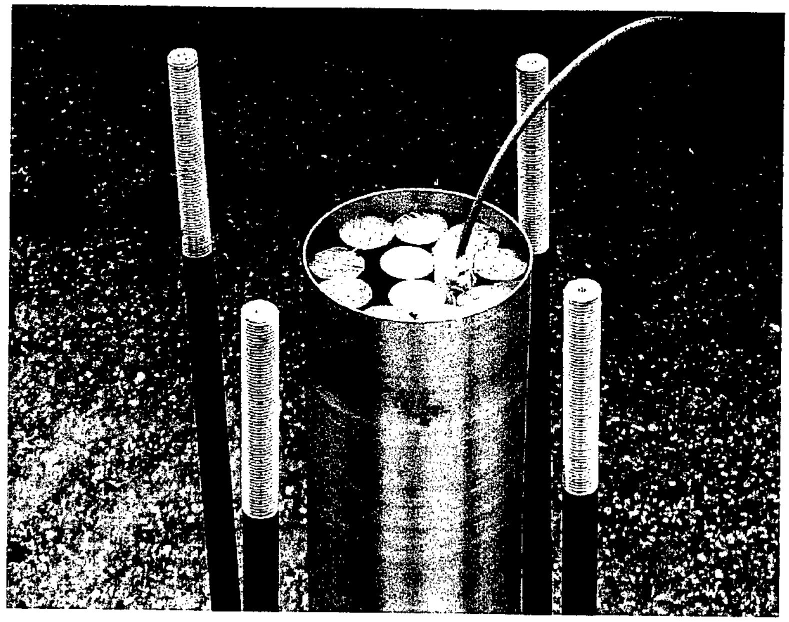


Figure 4. Steel test shell with Lexan rods representing grenade stacks.

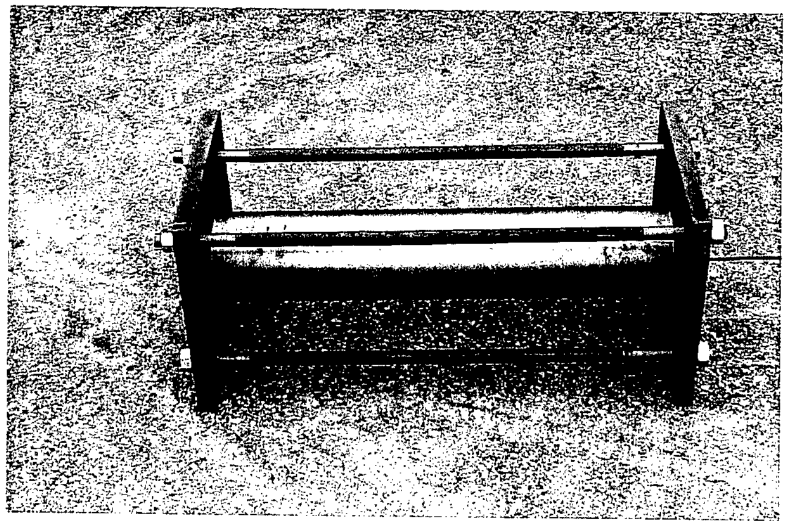


Figure 5. Test warhead mounted between two armor plates.

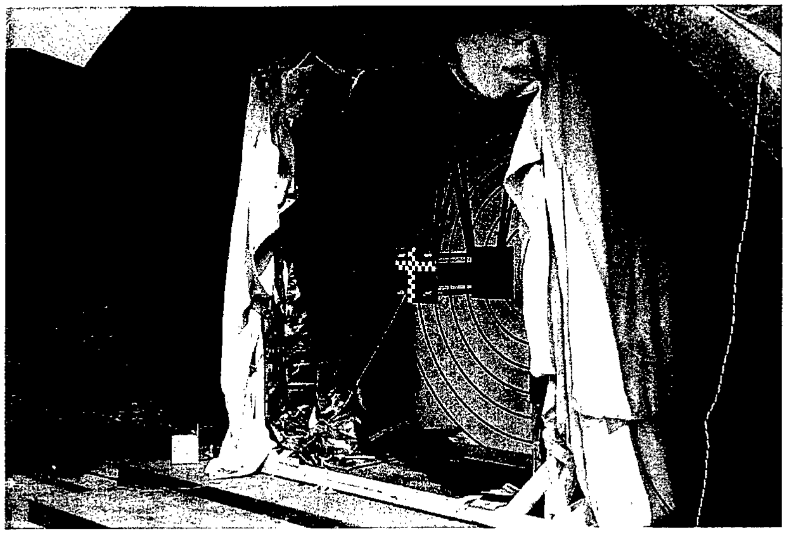


Figure 6. Test item in Kevlar tent.

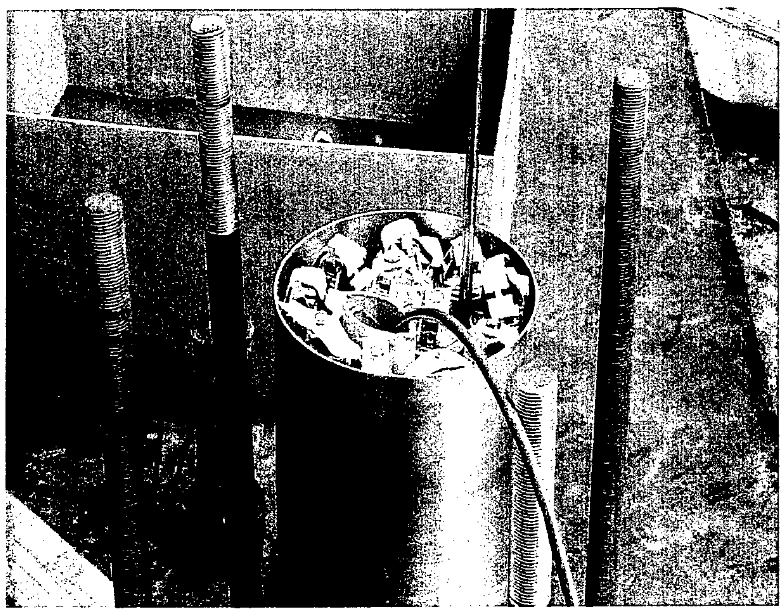


Figure 7. Test warhead packed with inert M-80 grenades.

Figure 8. Actual composite warhead shell with inert M-80 grenades.

3. Test Results

Pressure records indicate that the burst pressure of the first case with the Lexan rods as grenade simulators was 1,850 psi (12.7 Mpa), slightly lower than the design burst pressure of 2,000 psi (13.8 MPa). The shell fractured along one side and dispensed the Lexan rods. No modification of the charge mass was necessary for the second test. The remains of the shell can be seen in Figure 9, where the steel shell has wrapped itself around one of the support posts. This was expected.

The second pretest was performed with grenades in place of the Lexan rods. The pressure was significantly lower at approximately 1,000 psi (6.9 MPa). Grenade velocity was determined to be approximately 75–104 f/s (24–34 m/s).

The actual test of the composite warhead with grenades was then performed with the same charge level. As in the second pretest, the burst pressure was lower than expected. In both cases, it is theorized that the internal pressure first presses on the grenades; then, the grenades produce a point load on the shell wall as opposed to an even pressurization, fracturing it early. However, grenade velocity is within an acceptable range of 75–104 f/s (26–34 m/s). Figure 10 shows a sequence of two video frames of grenade expulsion at 22 and 24 ms. Figure 11 is a photograph of the largest remaining portion of the burst shell. This is very similar to shell remnants found with burst tests of the HICAP projectile.

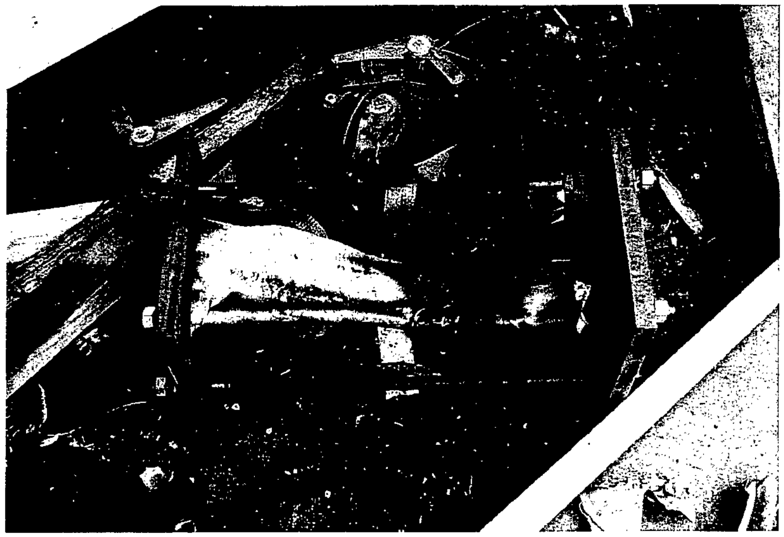
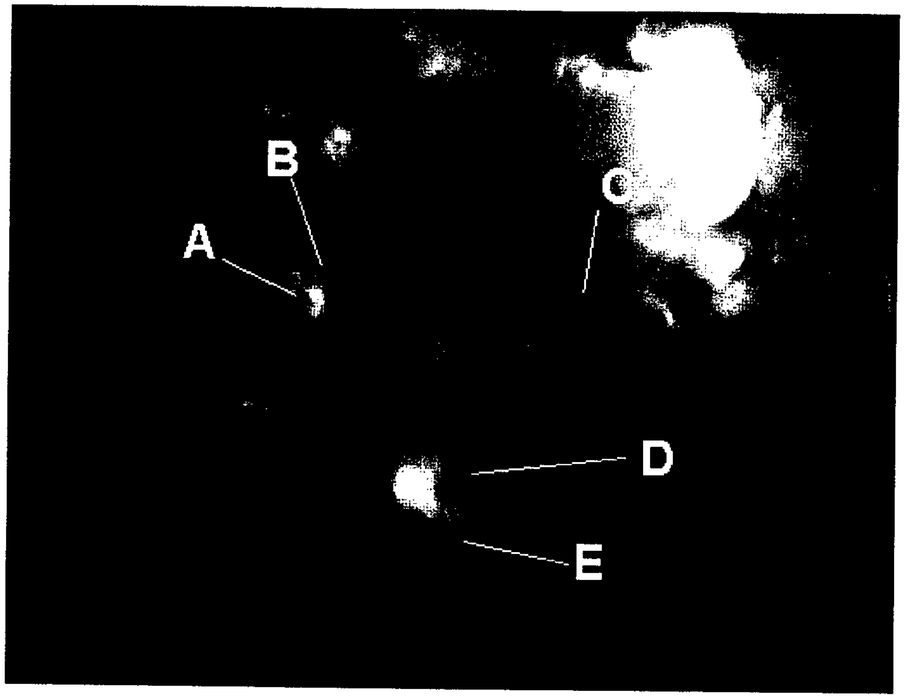


Figure 9. Simulated warhead case after expulsion.

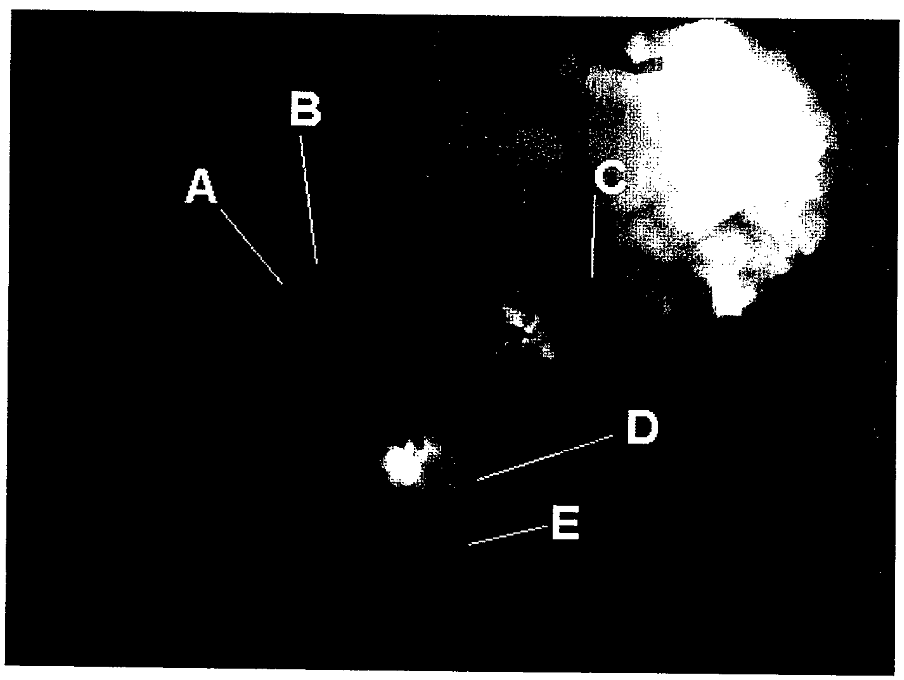
4. Discussion

The Lexan rods in the first of the three tests allow a general pressurization of the shell since they are made of a lower stiffness material than the steel body grenades and do not produce a point load on the shell. It was not possible, nor valuable to measure the velocity of the expelling Lexan rods, as they only simulated volume occupancy and not expelling mass. In the following tests, the grenades that expelled and contacted the steel rods were of no value in the experiment. The grenades that had a clean expulsion and could be seen clearly in the videos were the ones used to determine velocity and are listed in Table 1. Once the expel velocity is established, an optimal height of burst can be determined to produce an effective pattern and density on the ground. The only firm requirement is that the grenades have sufficient time to self-orient downward in descent for an upright landing, approximately 500 ft (161 m).

These tests are being performed at Yuma Proving Ground before stadia tests to establish acceptable expulsion and determine the optimal height of burst. One further ground test will be performed with an actual warhead, without constraints of plates and rods, to ensure that the tactical end caps will be of sufficient strength to ensure radial expulsion, just as the laboratory end caps did.



Frame at 22 ms.



Frame at 24 ms.

Figure 10. Two consecutive video frames of grenade expulsion at times of 22 and 24 ms. Lettered grenades used to estimate expulsion velocity based on their travel from their position in the previous frame.

Figure 11. Section of composite case after expulsion.

Table 1. Expel velocities of grenades in Figure 10.

Grenade	Velocity ft/s (m/s)
A	75 (24)
B	75 (24)
C	83 (27)
D	82 (27)
E	104 (34)

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REPORT DOCUMENTATION PAGE

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1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 2001	Final, June 1997–December 2000

4. TITLE AND SUBTITLE
Burst Test of the Best Buy Warhead

5. FUNDING NUMBERS
62618AH80

6. AUTHOR(S)
James M. Bender

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: AMSRL-WM-MB
Aberdeen Proving Ground, MD 21005-5069

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-2560

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Naval Surface Warfare Center
Code G30
Dahlgren, VA 22448

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
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12b. DISTRIBUTION CODE

13. ABSTRACT*(Maximum 200 words)*

The Best Buy program is a U.S. Navy development effort with the objective of gun launching a 5-in (127-mm) diameter, rocket-assisted, guided projectile to a range of 100 nautical miles (184 km) where the cargo will be dispensed over the target area. It is fired from the Mark 45 cannon or its improved variant. The cargo consists of 143 U.S. Army M-80 grenades. The intended target set is identical to that of the Army's M483 and M864 155-mm projectiles. The Best Buy projectile's mission is to replace the need for the U.S. Navy to emplace U.S. Marine towed artillery assets ashore in an amphibious assault. The minimum requirements for the Best Buy projectile are that it must be fired from 25 nautical miles (46 km) offshore to reach targets inland by an additional 25 nautical miles. In anticipation of future range requirements, the range requirement was extended to 63 nautical miles (116 km), and 100 nautical miles (240 km) is desired. This report covers Phase 1 of the warhead development program performed by the U.S. Army Research Laboratory (ARL) working in cooperation with the Naval Surface Warfare Center, Dahlgren Division (NSWC-DD) at Dahlgren, VA.

14. SUBJECT TERMS
warhead, Best Buy, artillery, M-80 grenades

15. NUMBER OF PAGES
31

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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